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THE DEVELOPMENT OF TRANSPORT-SHIP POWER INSTALLATIONS DURING THE YEARS OF SOVIET ADMINISTRATION

By V. V. Kotsyubenko and L. P. Sedakov

The development level of shipbuilding is largely determined by the degree of perfection of ship power installations.

Abstract

The creation of high-tonnage tankers and fast dry-cargo freighters has become possible only ~~in connection~~ with the appearance of more powerful combined boiler-and-turbine units and diesel installations; the development of hydrofoil and air-cushion ships depends upon ~~the availability of~~ compact, light-weight gas-turbine and diesel installations; the mastery of nuclear energy has made possible the creation of qualitatively new ships with a virtually unlimited degree of independent action.

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Depending upon the type, designation, and operating conditions of the ships, appropriate power installations are being created for them in the Soviet Union, with high-speed diesel engines and cumulative reducing-gear trains or electrotransmissions, with low-rpm diesel engines operating on heavy fuel, combined boiler-and-turbine units or gas-turbine installations with free-piston gas generators (FPGG) or combustion chambers, and others. Progress in atomic physics and technology has made it possible to supplement this list with atomic power-engineering installations.

Prior to the October Revolution, almost no ships were being built in Russia for the merchant marine. Overseas shipments were conducted predominantly

by means of foreign steamship companies in chartered ships. It is indicative that in the prewar year of 1913 only 8% of the export freight was shipped out in Russian ships, and 85% of the merchant-marine tonnage was comprised by foreign-built ships.

The formation and development of the young Soviet republic required the adoption in 1925, by the Soviet of Labor and Defense, of an Act which confirmed the first prospective marine transport shipbuilding program in the Soviet Union.

The types and the designation of the ships that were to be built, as well as the basis for the production of ship machinery that had been formed in the prerevolutionary period predetermined the selection, for ships domestically produced in the 1925-1941 period, of installations with steam piston engines and solid-fuel boilers and installations with low-rpm internal combustion engines.

Starting with 1925, installations with triple-expansion steam piston engines or paired semisingle-pass double-expansion engines and standard fire-tube reversible coal-fired boilers, generating steam with a pressure of up to 16 kg/cm^2 at 300°C, were used on ships of varied designation -- from medium lumber carriers (with an installation power of 900-1,000 indicated horsepower) to icebreakers (with an installation power of 10,000 indicated horsepower).

The first domestically produced maritime transport ships with internal combustion engines, the construction of which started in the second half of the 1920's, were single-shaft refrigerator ships with a dead weight of 2,600 tons of the "Yan Rudzutak" type and two-shaft passenger diesel ships for the Crimea-Caucasus line of the "Abkhaziya" type. On these ships there

were installed two-cycle six-cylinder reversible compressor engines with air dispersion of the fuel, with a power of 1,900-2,700 effective horse power at 100/125 rpm, of the DKRV 65/86 type (Figure 1), designed and built by the "Russkiy Dizel'" plant.

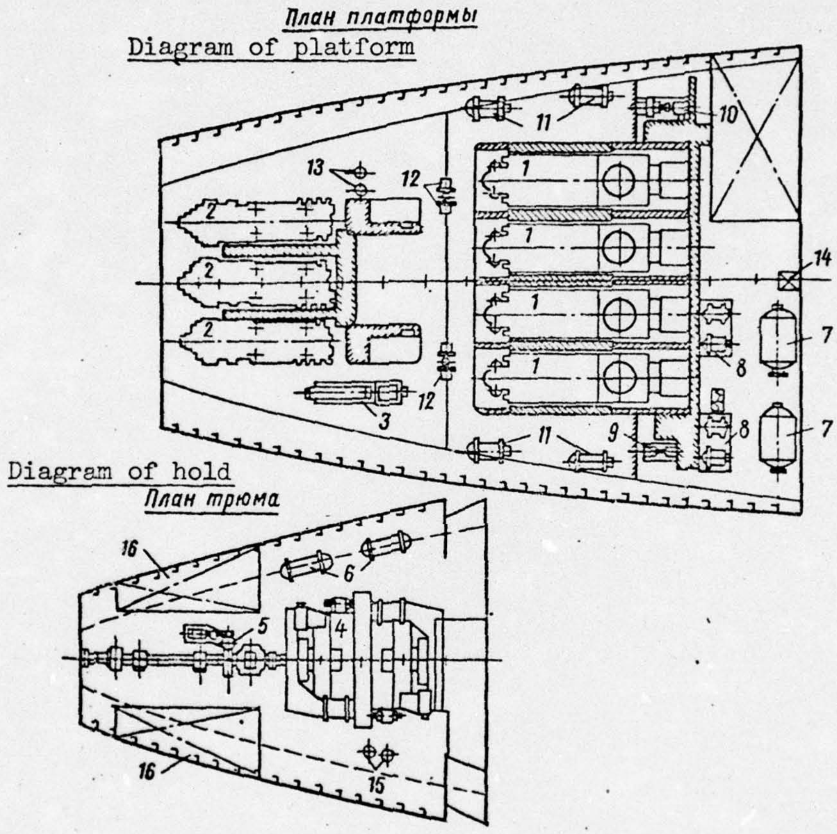

Figure 1. Location of mechanisms in the machine section of a refrigerator transport ship of the "Aktyubinsk" type.

1. Main 1375-kw diesel generator; 2. auxiliary 270-kw diesel generator; 3. layover 100-kw diesel generator; 4. propeller electric motor; 5. shaft-turning device; 6. water heater; 7. starting-air cylinder; 8. electric compressor; 9.-10. two-machine converters; 11. oil cooler; 12. fuel filters; 13. starting-air cylinder for the auxiliary and the layover diesel generators; 14. compressor-oil cistern: 15. foam generator; 16. boiler-fuel cistern.

The production of improved-design diesel engines of the DKRV 68/120 type, in four- and six-cylinder models with a power of 1,800-2,700 effective horsepower at 100 rpm, was mastered in the early 1930's. Ship engines with less power were being produced by the Kolomenskiy plant [in Kolomna].

On the basis of the engines of the "Krasnyy Dizel'" and the Kolomenskiy plants, as well as of some brands of imported diesel engines, installations ranging in power from 375 to 2,800 horsepower were designed and built in the postwar period for ships of varied designation (lumber carriers of the "Volgoles" type, diesel freighters of the "Kuybyshev" type, refrigerator ships of the "Volga" type, and others).

World War II interrupted the development of domestic transport shipbuilding and the production of ship machinery. The postwar years became a period of intense development of a domestic merchant marine and fishing fleet. In this period there also commences a new stage in the development of ship power engineering. For the construction of a transport and fishing fleet it was necessary to carry out, within brief time limits, experimental design and scientific research operations which would provide for the creation of power-engineering installations corresponding to the general level of the world production of ship power machinery, determine efficient types of power-engineering installations for ships of varied designation, organize the production and delivery of complementary mechanisms, automation facilities, devices, and instruments for them on the basis of extensive cooperation with adjoining branches of industry.

This development period of ship power engineering is characterized, besides what has been indicated above, by a rise in the capacities of the power-engineering installations and by a commencement in the application

of combined boiler-and-turbine units on merchant ships, which was connected not only with conditions of profitability in the operation of individual ships and of the entire transport fleet as a whole, but also with the possibilities of the domestic industry with respect to the creation of large-capacity power-engineering installations within short time periods.

Diesel Installations

The designing of ship diesel installations was based upon diesel engines of the 6 and 8DR 30/50 type with a power of 600 and 800 horsepower at 300 rpm, and of the 8DR 43-61 type with a power of 2,000 horsepower at 250 rpm designed by the "Russkiy Dizel'" plant, as well as upon the general-purpose industrial diesel engines of the D50 type with a power of 900-1,000 horsepower and of the D100 type with a power of 1,800 horsepower.

On the basis of these engines there were developed and created diesel installations with direct power transmission, diesel-reducing gear installations with a power of up to 4,000 horsepower, and diesel-electric installations with a power of up to 7,200 horsepower for low-draft tankers of the "Oleg Koshevoy" type, trawlers of the "Mayakovskiy" type, tankers of the "Kazbek" type, and fish canneries of the "Andrey Zakharov" type, dry-cargo ships of the "Dneproges" type, and others.

In spite of the fact that, during the creation of installations of the enumerated types, it was necessary to take into account the practicable possibilities of the nation's industry which was experiencing the consequences of the war, due to efficient planning it became possible to provide the shipbuilders with diesel installations corresponding to the world technical level which had at that time been attained.

Thus, the correctness of the decision to employ a diesel-reducing gear unit with 8DR 43/61 engines and a specially designed geared hydraulic transmission on tankers of the "Kazbek" type and ships of the "Andrey Zakharov" type was confirmed by the technical and economic indices as well as by the experience of foreign shipbuilding even in those countries, where the production of powerful low-rpm engines had been adopted. Such a technical decision made it possible to obtain an installation with 83 propeller rpm, which provides for the highest value of propeller efficiency for these ships. The created installation was distinguished by great stability, high maneuverability, and a number of other favorable operational properties.

As a result of the mastery of diesel-electric installations with a power of approximately 7,000 horsepower it became possible, for the first time in the domestic construction of transport vessels, to create high-speed ships (with a speed in excess of 16 knots). There was thereby made possible the construction of ships for the "UL" class to which corresponds, in the highest degree, the universality of the characteristics of electrical-propulsion installations. The effectiveness of such a decision was fully confirmed by the operation of ships under northern conditions, where in a number of instances they accomplished the escorting of convoys on an equal footing with icebreakers.

The diesel-electric installations of ships of the "Dneproges" and "Aktyubinsk" type (Figure 1) were distinguished by a relatively low weight-to-power ratio (65 kg/hp), a rather long service life (up to 30-40 thousand hours), the presence of remote control, and high stability by virtue of the possibility of traveling by means of four, three, two, and one diesel generators.

In recent years the type range of engines for the main installations of low- and medium-tonnage ships, as well as for use in making up the diesel-electric generators of ship electric power plants, was supplemented by engines of the ChN18/22 type with a cylinder power of 25-40 horsepower at 750 rpm, of the ChN25/34 type with a cylinder power of 50-75 horsepower at 500 rpm, and of the ChN36/45 type with a cylinder power of 100-200 horsepower at 375 rpm. These engines, created for use on ships of the transport fleet and the fishing fleet, are on the same level with respect to their principal properties as are foreign-made engines of such a class.

A large role in providing for the construction of marine transport ships was played by adoption, by the Bryansk Machine-Building Plant in 1961, of the production of powerful low-rpm diesel engines of the DKRN 50/110 and DKRN 74/160 type under license from the Burmeyster of Vayn firm.

On the basis of these engines there have been designed and built single-shaft diesel installations with a power of 2900-8750 horsepower at 170-115 rpm, in particular for lumber carriers of the "Sukhonales" type and dry-cargo ships of the "Bezhitsa" type.

Besides this, on the basis of imported engines with dimensions of 74/160 there have been created single-shaft diesel installations with a power of 7,500 horsepower for dry-cargo ships of the "Poltava" type and twin-shaft installations with a total power of 15,000 horsepower for the "Sovetskaya Ukraina" and "Sovetskaya Rossiya" whaling bases with a displacement of 45,000 tons.

With respect to the properties of the mechanical equipment, the adopted circuits, economy in operation, and the degree of automation the power-engineering installations of ships with low-rpm diesel engines are not inferior to the machine installations of similar ships built abroad.

The transition of the Bryansk Machine-Building Plant to the series production of diesel engines with second-degree supercharging (mean effective pressure 8.55 kg/cm^2 in comparison to 7 kg/cm^2 in the diesel engines produced earlier) will permit the use of engines with aggregate and unit power for making up the machine installations, and will thereby provide for a further rise in the technical and economic indices of ship installations.

A particular place in the transport fleet is occupied by marine and river passenger hydrofoil ships. The machine installations of these high-speed vessels have been created on the basis of light-weight high-speed diesels of the ChN 18/20 type which, with respect to their indices, are not inferior to similar specimens of foreign-built engines.

The prospective planning of ships requires for planning organizations, branch institutes, and industrial establishments the solution of a series of important problems with respect to the further improvement of diesel power-engineering ship installations. These include, above all:

-- a further rise of the reliability and service life of the equipment;

-- a rise in the efficiency of diesel installations due to improvement of the engines as well as to extensive utilization of the heat lost with the exhaust gases and in the cooling systems;

-- extensive introduction of the comprehensive automation of diesel installations;

-- expansion of the range of diesel engines produced by the domestic industry, including low-rpm engines;

-- the creation of combined units with medium-power diesel engines for ships of the fishing fleet, which provide for their efficient use both for propulsion of the ship and for satisfying its requirements for electric power.

Steam-Turbine Installations

In 1954, in connection with expansion of the Soviet Union's international economic relations shipbuilding and allied branches of industry were faced with the problem of creating, within short periods of time, series-produced heavyweight dry-cargo ships and tankers. The assigned tonnage and high speed of these ships, as well as the close construction deadlines, predetermined the selection for them, as the principal engines, single-shaft steam-turbine installations with a power of 13,000 and 19,000 horsepower. In 1959 there were put into operation the leading ships -- the "Leninskiy Komsomol" dry-cargo freighter and the "Praga" tanker (Figure 2), and in 1963 the "Sofiya" tanker. The employment of steam-turbine installations on ships of the transport fleet constituted a new technological trend for domestic shipbuilding and ship-machinery construction. There arose the necessity for taking into account a number of specific requirements faced by the power-engineering installation of transport ships, such as the provision of high efficiency, prolonged operation at nearly-full capacities, a considerably longer engine service life, and others.

With the aim of creating profitable steam-turbine ship installations corresponding to the level attained at that time abroad, it became necessary to proceed to higher initial steam parameters than those that had been accepted in the prewar period, a regenerative thermal scheme with steam takeoffs from the GTZA* and to create highly efficient basic equiupment -- boilers, turbines, auxiliary mechanisms.

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*Translator's Note: An expansion of GTZA is not provided anywhere in the text of this article; the term is not contained in the Library of Congress' Glossary of Russian Abbreviations and Acronyms [Washington, 1967], nor in any source consulted at the Library of Congress itself.

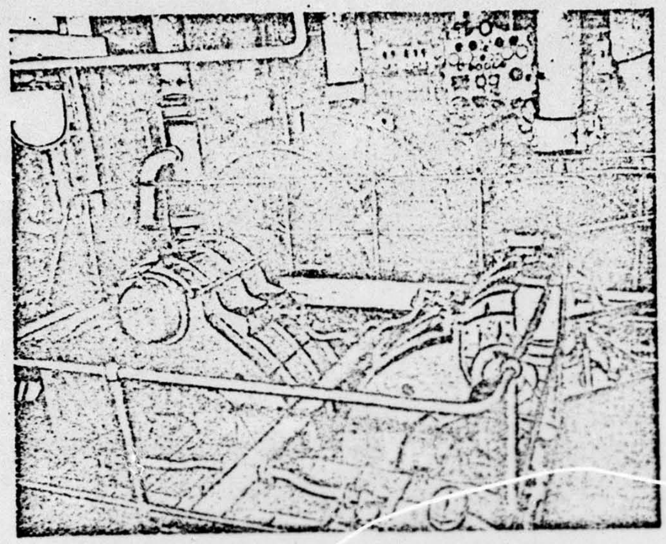

Figure 2. Machinery section of a tanker of the "Praga" type (GTZA and the maneuvering device panel).

Thus, for these installations boilers with an efficiency of 93% were produced, working on liquid fuel, with improved nozzle devices, equipped with economizers and steam reheaters, generating steam at a pressure of 42 kg/cm^2 and a temperature of 450-470°C. The main geared-turbine units, developed by the Kirov plant in Leningrad, had a sufficiently high effective efficiency and provided for reliable and prolonged operation of the installation.

With respect to the power-engineering installation, the high degree of perfection of the basic equipment, the automation level, and the economy, the first domestically produced steam-turbine installations for transport ships were virtually indistinguishable from the majority of the steam-turbine installations of ships built abroad during the 1950's.

Planning studies recently conducted by scientific research institutes, by design offices, and by the industry make it possible to determine the

basic technological trends of the forthcoming development of steam-turbine ship installations. The results of these works are reflected to the highest degree in the project of a highly economical steam-turbine ship installation with a power of 25,000 horsepower, the creation of which, however, requires the accomplishment of a number of essentially new technological decisions.

On the basis of technical and economic research, a basis is provided for the expediency of increasing the initial steam parameters (the pressure to 80 kg/cm^2 and the temperature to 515^oC). Here account was taken of the necessity for providing prolonged operational reliability of the installation elements with the use of perlite-class steels, which have been adopted by the industry and have undergone prolonged operational testing in stationary practice.

For increasing the cycle efficiency of the steam-turbine installation, provision has been made for intermediate steam reheating, for developed regenerative heating of the feed water due to five steam takeoffs from the GTZA, and for other improvements.

Measures have been planned for increasing the efficiency of the basic power-engineering equipment and for improving its performance characteristics. The efficiency of the main boilers will be brought to 96%; their heating devices will provide for the possibility of decreasing the air-excess coefficient to values of 1.01-1.02 (on existing installations to 1.2). With the aim of improving the large-dimensional indices of the boiler, provision has been made for regenerative rotating air heaters. Total screening of the combustion chamber, during which the necessity for lining it is excluded will be accomplished for the first time. The effective efficiency of the GTZA will be brought to 82% instead of the 78% achieved on the existing

installations. Provision is also made for a single-plane grouping of the GTZA with axial exhaust of stem into the condenser, this making it possible to situate the boilers over the GTZA, which permits the length of the machinery section to be substantially decreased. A reducing-gear train of an improved type, with splitting of the power from the high-pressure turbine and the low-pressure turbine, will be used.

The tendency for maximum improvement of the weight and dimensional characteristics of the GTZA, and of the installation as a whole, has led to the creation of a comprehensive unit in which are united the main turbines with the current generator and the feed pump mounted on them, the reducing-gear train, the oil system, and the main condenser, as well as the high-pressure heater. The high degree of aggregation considerably simplifies the installation, reduces to a minimum the length of the external pipelines, facilitates and simplifies mounting the installation on the ship.

The use of high steam parameters, an improved thermal scheme, and more economical basic power-engineering equipment make it possible to expect the attainment of a specific fuel consumption of approximately 180 g/hp-hour (in the power-engineering installation of tankers of the "Sofiya" type it comprises 240 g/hp-hour).

Thus, the creative collaboration of scientific research workers, planners, and plant personnel of the shipbuilding and ship-machinery construction industry predetermines the possibility of the further improvement of steam-turbine installations for heavyweight and high-speed ships.

Gas-Turbine Installations

Research and planning operations on the creation of gas-turbine ship installations were started in the USSR even before World War II. After the

war these operations proceeded in two directions: along the course of utilizing the experience of ship steam-turbine construction and along the course of tuilizing the extensive experience of aviation, where the application of gas-turbine engines had caused a genuine technological revolution.

Along with the solution of problems faced by the developers of gas-turbine installations of all types (the preparation of materials for highly stressed gas-turbine-installation subassemblies working in the field of high gas temperatures, the provision of highly efficient turbine machinery with relatively small dimensions), with respect to gas-turbine ship installations it becomes necessary to solve an entire series of very specific problems. Among these it is necessary to include, first of all, the provision of reliable operation of all gas-turbine-installation elements under maritime conditions. For increasing the operating economy of gas-turbine transport ships of the displacement type it is necessary, along with the development of highly efficient compressors and turbines to utilize the heat of the exhaust gases. With this purpose the heat of the spent gases may be utilized either in a regenerator or in a special utilization circuit, the useful power of its turbine being added to the power of the gas-turbine installation itself. By means of the indicated facilities, the specific fuel consumption in a gas-turbine installation of this type can be brought to 200-225 g/hp-hour. An important problem in the field of gas-turbine ship installations remains the possibility of the combustion of inexpensive varieties of liquid fuel -- mazuts.

The first domestically produced example of a gas-turbine ship installation is the GTU-20 with a power of 13,000 horsepower, designed and built

by the Leningrad Kirov plant for the dry-cargo ship "Parizhskaya Kommuna" (Figure 3).

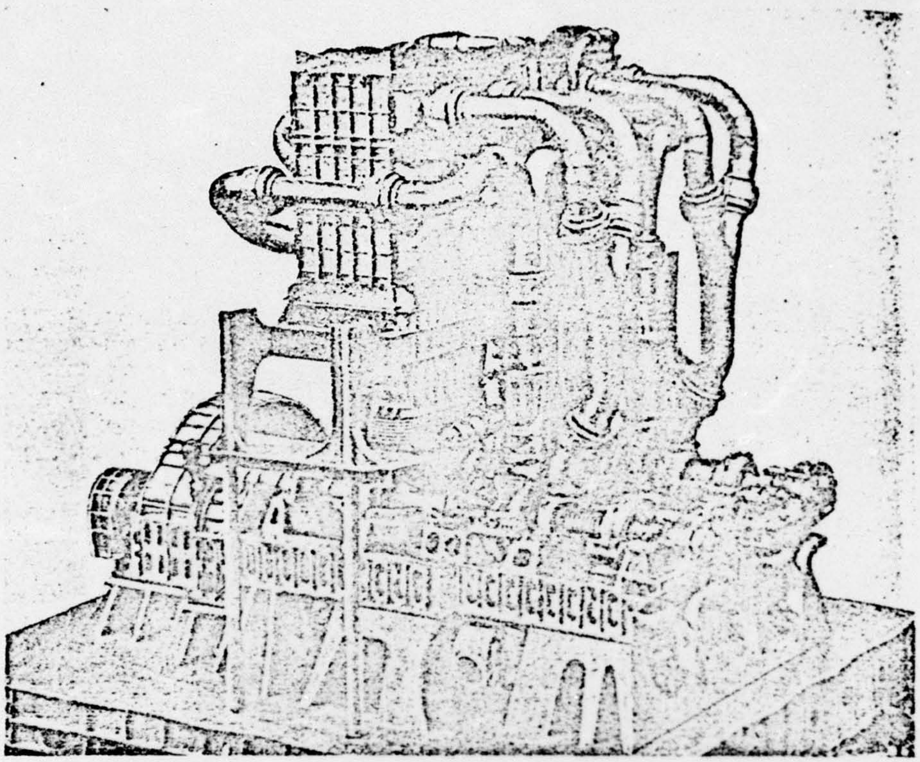

Figure 3. General view of the GTU-20

The relatively low weight and small dimensions make it possible to create, on the basis of gas-turbine ship installations, powerful floating electric power stations that are required for regions which are remote from electric power systems, where large-scale industrial construction is being initiated, and where the exploitation of mineral deposits is commencing.

The application of gas-turbine installations for hydrofoil and air-cushion vessels is particularly promising. For these vessels the determining requirement is a low weight of the power-engineering installation at high aggregate power. Converted gas-turbine aircraft engines (Figure 4) are being

used on hydrofoil and air-cushion vessels. Examples of such vessels are the vessels "Burevestnik," "Sormovich," and "Tayfun."

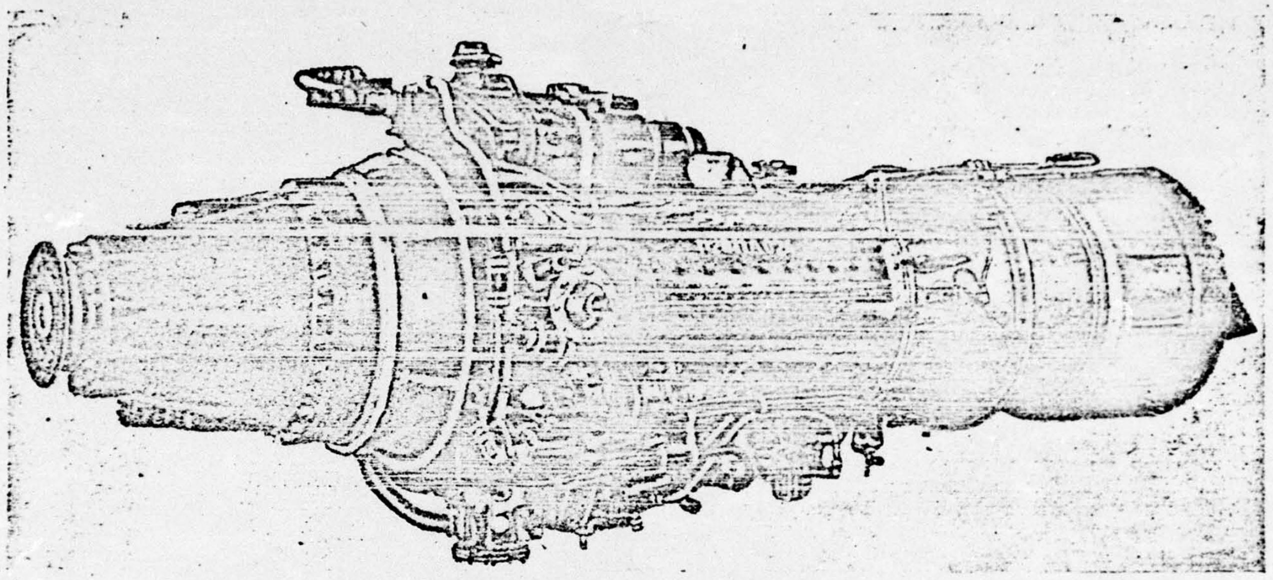

Figure 4. General view of the AN-20 gas-turbine engine

A particular place among gas-turbine installations is occupied by installations with free-piston gas generators (FPGG). A series of theoretical, planning, and experimental investigations has been conducted in relation to these installations; these investigations have demonstrated the technical and economic expediency of employing gas turbine installations with free-piston gas generators in shipbuilding. Such installations, which possess a high degree of economy approaching that of diesel installations, have good traction characteristics and a large service life at relatively small weights and dimensions. These properties of installations with free-piston gas generators, as well as the convenience of their placement in the machinery section and the possibility of operating on heavy grades of fuel,

predetermine their use on ships of the transport fleet and the fishing fleet within the power range of 5,000-6,000 horsepower.

Experience in the operation of a series of maritime lumber carriers of the "Pavlin Vinogradov" type, with French-built gas-turbine installations with a power of approximately 4,000 horsepower, has confirmed the high maneuvering capabilities, reliability in operation, and simplicity of repair and servicing of installations with a free-piston gas generator. The first ship produced by domestic plants with a gas-turbine installation and a free-piston gas generator, a medium fishing trawler with a power of 540 horsepower, has passed its running tests and is being put into experimental operation. Another installation with a power of 1,650 horsepower, designated for a dry-cargo river ship, has successfully passed static tests.

Figure 5 shows a general view of an OR-95 brand free-piston gas generator with a capacity of approximately 800 gas horsepower. At present there is being created a gas-turbine installation with a free-piston gas generator with a power of 3,400 horsepower for a large fishing trawler.

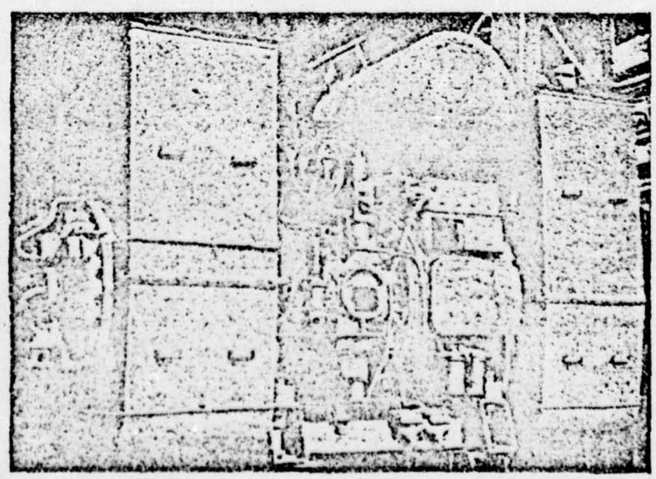

Figure 5. Free-piston gas generator of the OR-95 type.

Accumulation of experience in the operation of gas-turbine ships will permit a transition to be made to a more extensive application of gas-turbine installations on transport ships. This will also be faciliated by such advantages of the gas-turbine installation as adaptiveness to comprehensive automation, simplicity in servicing and aggregate repair, high maneuverability, as well as the presently completed extensive complex of scientific research and experimental design studies directed at increasing the economy and improving the other characteristics of gas-turbine ship installations.

Atomic Energy Installations

A new page in the development of maritime transport is being opened by the use of atomic energy installations on icebreakers and transport ships.

Advances in the field of the development of nuclear physics and engineering made it possible for our country to undertake, already in 1956, the construction of the first nonmilitary atomic ship in the world -- the icebreaker "Lenin" -- at the Admiraltiyskiy plant. Operation of the "Lenin" icebreaker for a number of years has confirmed the possibility of providing for reliable and safe operation of the atomic energy installation, and has demonstrated in practice the merits of use of atomic energy on ships.

The enumerated achievements permit the assertion to be made that the extensive introduction of nuclear power engineering in shipbuilding, on the basis of conducted research and engineering achievements, is a question of the immediate future.

Atomic installations will find application along with combined boiler- and turbine units, diesel, and gas-turbine installations, and their creation

not only does not contradict, but at a certain stage reinforces the development of contiguous domains of ship power engineering.

from p 1 ~~In conclusion,~~ It may be stated that during the years of Soviet rule, ~~and particularly in the period~~ after the Great ~~Patriotic~~ War, on the basis of efficient planning which combines the requirements of shipbuilding and the practicable possibilities of domestic machine building, all types of modern power-engineering ship installations were ~~have been~~ created for maritime, fishing, and river ships, which are not only not inferior to the world technological level, but which in a number of instances exceed it.

Further development of the transport fleet of the Soviet Union places new problems in front of shipbuilding and the contiguous branches of industry.

The technological level of the domestic production of ship machinery makes it possible to provide for the construction of improved, modern and promising ships for the national economy of the land.